

SAFETY TROCAR ASSEMBLY

Field of the Invention

The present invention relates to medical equipment, in particular to trocar and similar devices used in surgical procedures and intended for their improvement.

Background of the Prior Art

Trocars are used in medicine for making [openings in body cavity walls used further as ports for instrument insertion to a body cavity and diagnosis and treatment. When trocar is inserted to body cavity, there is a real danger of interior organ injury by piercing-cutting means entering the body cavity and located at the trocar distal end.

To prevent such a complication, the trocars are equipped with various protectors of piercing-cutting means. However, all known solutions do not eliminate totally the acuity of the problem of accidental puncture wounds of internal organs upon trocar performance.] orifices and trocar port placement in body cavity walls used further for diagnostic or surgical instrument insertion into body cavity. Trocar insertion into body cavity can be accompanied with internal organ injury. To prevent such a complication, the trocards are equipped with various protectors of piercing-cutting means. However, all known solutions do not eliminate the problem of internal organ injuries.

The safety trocar penetrating instrument is known from the US patent No. 5591190, comprising port unit and trocar unit with obturator [on whose distal end there is a] having piercing-cutting means. The device is equipped with protector for piercing-cutting means made as a tubular shield situated between obturator and tubular cannula of port unit and movable relative to obturator [within the range] from the extended position when it encloses piercing-cutting means and prevents it from any contact, to the retracted one, when piercing-cutting means is open and can [opening in] perforate the body cavity wall. Such a protector advances to the extended position when the [force applied to its distal edge on the side] resistance of body cavity wall [is removed, which occurs after complete exit of] drops after the exposed piercing, cutting means [to] has already entered the body cavity, i.e. after internal organs could have already been injured.

Another trocar and cannula assembly are known from the USA patent No. 5246425, [which are equipped with] wherein a tip protector [comprising] comprises a plurality of projections which,

by the author's idea, should be [actuated] displaced into an extended position before the piercing apex has been fully inserted [to] into the body cavity. However, [design predetermines] such mechanism leads to inevitable injury of body cavity wall, increased resistance to the device advance, the device advance in jerks, and high probability of protector jamming. [i.e. protector does not advance to the extended position upon tip exit into body cavity, and as a consequence, internal organs are injured. Drawbacks are the result of the fact that several piercing members are present, that is the tip and the protectors themselves. When] Moreover, when these members pass through fibrous anatomical structures: aponeuroses, fascias, muscles, the structure fibers enter either the projections, or between the projections and tip [therefore]. Further device advance is possible solely by rupturing these fibers which, in its turn, results in increased tissue injury and in the device hindered advance.

The tissue fibers incorporated between projections and tip can jam protector in the retracted position. In this case the jeopardy of internal body injury is even higher than by the performance of a trocar non-equipped with protector, since a surgeon, being sure of the device safety, operates with less caution.

[In addition to the protection of patient's organs, the protector is intended for guarding medical personnel from accidental puncture injuries. For this aim the protector is equipped with locking mechanisms which fix it in the extended position. Such locking mechanism is described in the USA Patent No. 5246425. locking means ensures protector fixing in the extended position for any trocar unit position relative to port unit, including the completely assembled one. There are the means for the protector manual de-blocking which preclude the lock mechanism automatic operation. With such a design it is upon the surgeon to decide when lock mechanism should be activated.

Hence, if the surgeon forgets to do it, trocar unit is removed of port unit with inactivated lock mechanism and it is dangerous because medical personnel, being sure of its complete safety, handles the trocar more carelessly. If, by trocar unit setting into port unit, the locking mechanism is inactivated, the port unit sealing means shift it to the retracted position by interacting with protector. Thus, piercing-cutting members pass unprotected through the sealing means area, and can bring to the trocar unit jamming in port unit, or damage sealing means, which results in violation of its de-sealing properties.

Hence, lack of automatically supported link between the device readiness to tissue piercing and locking mechanism condition distract the surgeon to the locking mechanism control, which is

inconvenient and unreliable.]

A trocar with a shield is [known from the] disclosed by US patent No. 5797943. The geometry of the described [in the patent] shield should, by the authors' opinion, ensure successive protection of various zones in piercing-cutting means practically simultaneously with their penetration to the body cavity. However, shield members have such sizes, shape, arrangement and contact zone with body cavity wall that they generate considerable resistance between the shield and the body cavity wall tissues, and [it] the latter holds the shield in totally retracted position, up to the shield complete removal beyond the bounds of body cavity wall, which means that no successive protection of piercing-cutting members takes place as they enter the body cavity.

Similar demerit is found in USA patents No. 5690663, 5709671. A trocar, having improved tip configuration is [known from the] disclosed by US patent No. 5709671, where distal edge of tubular cannula is made sloping, to facilitate the device passing through body cavity wall. In fact, the surgeon has less difficulties in trocar passing through tissues since sloping edge of cannula operates as a wedge giving the benefit of force, which facilitates tissue rupture by trocar passing. But tissue injury during the trocar performance remains considerable.

[All above described devices lack the means for sealing spacing between cannula and body cavity wall; they also do not have means for hemostasis out of the orifice edges into body cavity wall. These devices do not have reliable means precluding displacement and complete port drop out of body cavity wall.

The US No. 5556411 is known comprising cannula-retaining means made as a movable along the cannula member with sticky surface flanges, which sticks to a patient's skin and ensures cannula fixation.

However, this fixation is insufficiently reliable and does not ensure body cavity sealing.]

Summary of the Invention

[To facilitate an appreciation of the significance of various features of the present invention, reference is made herein to a range of "objectives". It should be clearly understood, however, that these objectives are not intended as a definitive statement that any particular embodiment described herein satisfies all of these objectives.]

The invention objective is the decrease of internal organ injury risk upon trocar performance. Another invention objective is increased reliability of protector operation by preventing jamming and engagement of body cavity wall tissues between the members of trocar distal edge.

Another invention objective is decreased tissue injury of body cavity wall.

Another invention objective is facilitated trocar passing through body cavity wall.

Another invention objective is decreased material consumption for the device, design simplification and device low-cost manufacturing.

[Another invention objective is trocar performance easiness.

Another invention objective is increased safety of medical personnel by trocar operation.]

Another invention objective is independent of each other operation start and finish of cutting members dependable on tissue local biomechanical properties.

Another invention objective is accurate adaptation of orifice sizes in body cavity wall to the cannula diameter.

[Another invention objective is improved body cavity sealing and precluded gas discharge through the spacing between cannula and orifice edges in body cavity wall.

Another invention objective is ensured hemostasis on the edges of trocar-generated orifice.

Another invention objective is improved fixation of portal unit in the orifice in body cavity wall.

Accordingly, certain preferred embodiments of the present invention provide a trocar assembly including a low-profile retractable shield deployed immediately adjacent to a cutting element with a cross-sectional area which is small relative to the total cross-section of the assembly. In preferred examples, the total cross-sectional area protected by the shield element is less than about 0.4, and most preferably less than about 0.2, of the total cross-sectional area of the assembly. As a result, the shield extends itself as soon as the cutting element clears the tissue wall, prior to penetration of the remainder of the end portion of the assembly. Optionally, such a shield may be used in combination with a conventional, large-area shield to provide two-stage protection.

In fuller structural terms, there is provided a safety trocar assembly comprising:

- portal unit with elongated, tubular cannula having an open distal end;
- trocar unit having elongated obturator adapted to be removably inserted through cannula and having a penetrating end exposed through open distal end of cannula and comprising a]

The above noted objectives are accomplished by a safety trocar assembly having a portal unit with elongated obturator removably inserted through the cannula and having a handle on its proximal end and a penetrating end on its distal end. The penetrating end is exposed through the cannula open distal end and has a cutting means, a penetrating apex, and a sloping side wall immovable relative to obturator. The obturator is provided with a protector means having a bias means and a movable

penetrating apex shield that in its retracted position opens the penetrating apex and in its extended position closes the penetrating apex preventing it from any contact with patient's organs. In the projection onto transverse plane, the obturator sloping side wall surrounds the penetrating apex shield. It means that the penetrating and, consequently, also the penetrating apex shield have little cross section dimensions in comparison with the obturator. This allows reduction of the resistance of body tissue during penetrating apex shield displacement to its extended position and provides fast acting protection of the penetrating apex immediately after the penetration of penetrating apex distal end into the body cavity, however, before the penetrating end has been fully inserted. Further dilation of the orifice in the body wall is carried out by cutting means located on the sloping side wall. The penetrating apex shield is made tubular of circular or flattened cross section, totally closed or having a slot on one side. The distal edge of this shield forms a fence precluding the introduction, jamming, and engagement of tissue fibers of the body cavity wall between the penetrating apex shield and the penetrating apex as well as between the penetrating apex shield segments. As a result, the injury of body cavity wall is decreased and trocar passing through body cavity wall is facilitated.

The shield for protection of the cutting means is characterized by a local comparative height equal to the ratio of local maximal shield height to a local maximal shield width measured in the same local obturator transverse plane. This parameter characterizes such properties of the protector shield as the resistance of body tissue to shield displacement to its extended (protected) position and velocity of this displacement. The less the value of this parameter the less the tissue resistance and the faster the shield displacement to extended position. According to the present invention, the shield, particularly made plate-shaped, has maximal value of the local comparative height less than 0.5. This shield is a low profile shield and the perimeter of its cross section insignificantly exceeds the perimeter of tissue incision made by the cutting means. Moreover, the height of this plate-shaped shield (the plate thickness) amounts 0.4 to 2 mm for obturator with outer diameter 10 to 12.5 mm and 0.4 to 1.2 mm for obturator with outer diameter 5 to 6.5 mm. This shield is a fast acting protector entering the tissue incision without substantial resistance of tissue incision edges and enabling the shield entry the body cavity immediately after entry there the cutting means. As a result, the risk of patient internal organ injury is significantly decreased.

In version embodiment, a safety trocar assembly comprises a penetrating means with at least two penetrating zones and a protector means with independent protector members, made as shields, for independent protection of each of said penetrating zones, and a resilient bias means for each of the protector members. This protects the penetrating zone (knife) which enters the body cavity

independently of another penetrating zones (knives) which have not yet entered the body cavity and continue to cut the tissue. In version embodiment, there are distal and proximal penetrating zones provided with a distal and a proximal independent shield, respectively. The distal penetrating zone is the first one that enters the body cavity and is a main cause of internal organ injury, so its independent and fast protection eliminates trocar procedure complications.

In version embodiment, the displacement of the proximal shield from the extended position to the retracted position demands greater force than identical displacement of the distal shield. That can be achieved by larger rigidity of the bias means (in the form of a spring) of the proximal shield than one of the distal shield. As a result, the proximal penetrating zone forms such final dimensions of orifice that is accurately adapted to the cannula outer diameter. Described penetrating and protector means have so simple a design (for example, making protector and biasing members as a one detail) so as to permit their arrangement in the limits of obturator distal part. Such implementation increases trocar reliability and reduces its manufacturing cost.

[Original pages 5-16, and page 17, lines 1-23 are deleted.]

Brief Description of the Drawings

Various embodiments of the safety trocar assembly of the subject application will be described below with reference to the following drawings wherein:

Fig. 1 is a perspective view of trocar assembly with tubular penetrating apex shield.

Fig. 2 is a longitudinal section of trocar assembly of the Fig. 1.

Fig. 3 is a perspective view of trocar assembly with spring penetrating apex shield.

Fig. 4 is a perspective view of distal part of trocar assembly of the Fig. 3

Fig. 5 is a longitudinal section of trocar assembly of the Fig. 4 and demonstrates penetrated apex shield in extended position.

Fig. 6 is a longitudinal section of trocar assembly of the Fig. 4 and demonstrates penetrated apex shield in retracted position.

Fig. 7 is a perspective view of trocar assembly with groove penetrating apex shield.

Fig. 8 is a longitudinal section of distal part of trocar assembly of the Fig. 7 with groove shield in extended position.

Fig. 9-11 are sections of trocar assembly of the Fig. 8 on the levels 9-9, 10-10, 11-11, respectively.

Fig. 12 is a longitudinal section of distal part of trocar assembly and groove shield of the Fig. 8.

Fig. 13 is a longitudinal section of distal part of trocar assembly of the Fig. 7 with groove shield in retracted position.

Fig. 14 is a longitudinal section of distal part of trocar assembly and groove shield of the Fig. 13.

[Fig. 15 is a perspective view of trocar assembly with tubular shield and locking means for it.

Fig. 16 is a longitudinal section of the Fig. 15.

Fig. 17 is a perspective top view of trocar unit of trocar assembly of the Fig. 15.

Fig. 18 is a longitudinal section on level 18-18 of the trocar assembly of the Fig. 17.]

Fig. [19] 15 is a perspective view of trocar assembly with two independent tubular shields.

Fig. [20] 16 is a left-hand view of device of the Fig. [19] 15.

Fig. [21] 17 is a longitudinal section of device of the Fig. [19] 15.

Fig. [22] 18 is a longitudinal view of trocar unit of device of the Fig. [21] 17.

Fig. [23] 19 is a perspective view of the trocar unit of the Fig. [22] 18.

Fig. [24-29] 20-25 demonstrate successive changes in mutual positions of the shields at the stages of trocar penetrating end passing through body cavity wall.

Fig. [30] 26 is a perspective view of trocar assembly with low profile protector.

Fig. [31] 27 is a knife-side view of distal part of trocar assembly of the Fig. [30] 26.

Fig. [32] 28 is a left-hand view of the trocar assembly of Fig. [30] 26.

Fig. [33] 29 is a protector-side view of distal port of trocar assembly of the Fig. [30] 26.

Fig. [34] 30 is a longitudinal section of distal part trocar assembly of the Fig. [33] 29.

Fig. [35] 31 is a longitudinal section of the distal part of trocar assembly of the Fig. [33] 29 with protector displaced to retracted position.

[Fig. 36 is a perspective view of trocar assembly with blunt penetrating apex.

Fig. 37 is a distal part of device of the Fig. 36.

Fig. 38 is a top view of device of the Fig. 36.

Fig. 39 is an enlarged view of distal part of device of the Fig. 38.

Fig. 40 is a fragment of blunt penetrating apex.]

Fig. [41] 32 is a perspective view of trocar assembly with low profile inverted shield.

Fig. [42] 33 is a left-hand view of device of the Fig. [41] 32.

Fig. [43] 34 is a top view of distal part of device of the Fig. [41] 32.

Fig. [44] 35 is a knife-side view of distal part of device of the Fig. [41] 32.

Fig. [45] 36 is a shield-side view of distal part of device of the Fig. [41] 32.

Fig. [46] 37 is a longitudinal view of device of the Fig. [41] 32.

Fig. [47] 38 is a view of trocar unit of device of the Fig. [41] 32.

Fig. [48] 39 is a longitudinal section of distal part of device of the Fig. [41] 32 with shield in extended position.

Fig. [49] 40 is a longitudinal section of distal part of device of the Fig. [41] 32 with shield between extended and retracted positions.

Fig. [50] 41 is a longitudinal section of distal part of device of the Fig. [41] 32 with shield in retracted position.

Fig. [51] 42 is a perspective view of trocar assembly with two independent low profile inverted shields.

Fig. [52] 43 is a left-hand view of device of the Fig. [51] 42.

Fig. [53] 44 is an enlarged distal part of device of the Fig. [51] 42.

Fig. [54] 45 is a longitudinal section of distal part of device of the Fig. [51] 42.

Fig. [55] 46 is a distal part of device of the Fig. [51] 42 with shields between extended and retracted positions.

Fig. [56] 47 is a longitudinal section of device of the Fig. [55] 46.

Fig. [57] 48 is a distal part of the device of the Fig. [51] 42 with shield in retracted position.

Fig. [58] 49 is a longitudinal section of device of the Fig. [57] 48.

Fig. [59] 50 is a perspective view of safety trocar with three independent shields.

Fig. [60, 61] 51, 52 are views of distal part of device of the Fig. [59] 50 from knife-and shield-side, respectively.

Fig. [62] 53 is a longitudinal section view of distal part device of the Fig. [59] 50.

Fig. [63] 54 is a longitudinal section view of distal part device of the Fig. [59] 50 with plated shield in retracted position.

Fig. [64-72] 55-63 demonstrate positions of shields at various penetration stages of the distal part of Fig. [59] 50 device through body cavity wall.

[Fig. 73 is a perspective view of trocar assembly, wherein cutting elements in distal and proximal parts have dissimilar sharpness.

Fig. 74 is a distal part of device of the Fig. 73.

Fig. 75 is a top view of device of the Fig. 73.

Fig. 76 is a distal part of device of the Fig. 75.]

Fig. [77] 64 is a perspective view of trocar assembly, wherein proximal bias members of lateral shields are made more rigid than distal ones.

Fig. [78] 65 is a knife-side view of distal part of device of the Fig. [77] 64.

Fig. [79] 66 is a shield-side view of distal part device of the Fig. [77] 64.

Fig. [80] 67 is a longitudinal section view of device of the Fig. [79] 66.

Fig. [81] 68 is a longitudinal section view of device of the Fig. [79] 66 with plated shield in retracted position.

Fig. [82] 69 is a perspective view of trocar assembly with low profile inverted stepwise shield.

Fig. [83-85] 70-72 demonstrate the displacement stages of shield of device of the Fig. [82] 69 from extended to retracted position.

[Fig. 86 is a perspective view of trocar assembly, wherein tubular cannula has sloping edge and cutting means situated at least partially at the sloping edge level.

Fig. 87 is a distal part of device of the Fig. 86.

Fig. 88 is a top view of device of the Fig. 86.

Fig. 89 is a distal part of device of the Fig. 88.

Fig. 90 is a longitudinal section view of trocar assembly with mounting means.

Fig. 91-93 are sectional views of device of the Fig. 90 at 91-91, 92-92, 93-93 levels, respectively.

Fig. 94 is a longitudinal section view of portal unit of device of the Fig. 90.]

Detailed Description of Preferred Embodiments

Safety trocar assembly is intended for making orifices in body cavity wall and generation of conditions for subsequent introduction of instruments into a body cavity.

5 Before addressing specific implementations of the present invention in detail, it should be noted that the invention will be presented with reference to numerous examples, each of which illustrates one or more preferred feature of the invention. These various preferred features may each be used individually to advantage with an otherwise conventional trocar. In most preferred implementations, however, multiple preferred features are combined to provide a trocar with
10 greatly enhanced levels of safety to the patient and/or professional staff, and/or to provide numerous other advantages as will become clear from the following description.

Turning now to the Figures, Figs. 1 and 2 illustrate a first embodiment of a trocar assembly 1 in which a retractable shield 14 is deployed to selectively shield only the distal portion of a penetrating end 10. As a result, the shield extends itself as soon as the distal portion clears the
15 tissue wall, well before full penetration of end 10 occurs. [Preferably, the distal portion extends for less than about half of the axial length of the cutting elements measured parallel to the axis, and most preferably, no more than about a third of the length. Radially, shield 14 typically has a diameter of between about 3 and about 6 mm.]

More specifically, Fig. 1 shows trocar assembly 1, comprising trocar unit 2 and portal unit 3.
20 Fig. 2 shows a longitudinal section of trocar assembly 1 in enlarged scale. Portal unit 3 has tubular cannula 4, portal housing 5 and inner seals 6, 7 located in portal housing 5 and aimed to maintain insufflation of the body cavity. Tubular cannula 4 has an open distal end 8. Trocar unit 2 has elongated obturator 9 adapted to be removably inserted through cannula 4 and having a penetrating end 10 exposed through cannula 4 open distal end 8. Penetrating end 10 has
25 penetrating apex 11 and a sloping side wall 12. Longitudinal opening 17 of obturator 9 houses protector means 13 comprising tubular penetrating apex shield 14 adapted to actuate between a retracted position and an extended position (shown in Fig. 2), when shield 14 surrounds penetrating apex 11, and sloping side wall 12 surrounds shield 14 from the outside. Distal edge 15 of shield 14 forms uninterrupted hedge. Protector means 13 comprises bias means made as a compression spring 16. In the embodiment shown in Figs. 1, 2 penetrating apex 11 formed by
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pointed distal edge of cylindrical piece 18, having circular ledge 19 which is abutted by circular ledge 20 of penetrating apex shield 14, when shield 14 reaches its extended position. Stopper bushing 21 abutted by spring 16 is tightly placed on proximal end of cylindrical piece 18.

Device 1 is operated as follows:

- 5 Surgeon holds device 1 by housing 5 and push member 22 situated on obturator 9 proximal end. Device 1 is oriented approximately perpendicular to body cavity wall and is pressed to it, applying pushing effort to push member 22. The resistance force of pierced tissues applied to shield distal edge 15, displaces shield 14 towards retracted position so that penetrating apex 11 strips bare and pierces body cavity wall tissues. In this process, shield
- 10 uninterrupted distal edge 15 forms a hedge precluding the introduction and engagement of tissue fibers of body cavity wall between shield 14 and penetrating apex 11, thus ensuring smooth motion of device 1 through the tissues. When penetrating apex 11 and shield distal edge 15 have entered a patient's body cavity, however, before penetrating end 10 has been fully inserted, the force applied to shield distal edge 15 is removed, and spring 16 returns shield 14
- 15 to extended protected position, and further movement of penetrating end 10 to body cavity occurs with protected penetrating apex 11, which precludes the injury of inner organs. Penetrating apex 11 can have diversified shapes, for instance, conical or pyramidal one, with cutting edges (not shown in the Fig.).

Turning now to Figures 3-6, these illustrate a variant of the embodiment of Figures 1 and 2 in which the shield is implemented as a helical coil of resilient wire formed with a closed portion 114 acting as the shield and a spring portion 116 which provides forward biasing. In other respects (preferred dimensions etc.), this implementation is similar to the previous embodiment. More specifically, Fig. 3 shows safety trocar assembly 101, comprising trocar unit 102 and portal unit 103.

25 Fig. 4 shows distal part 123 of device 101 in enlarged scale, and Fig. 5 shows a longitudinal section of distal part 123. Penetrating end 110, protruding through cannula 104 open distal end 108, has penetrating apex 111 made integral with obturator 109, penetrating apex shield 114, and bias means made as a compression spring 116. In this, shield 114 and spring 116 are made as a single piece from coiled springy rod fixed in obturator 109 circular groove 124. Penetrating end 110 also has sloping side wall 112, whereon outer cutting means 125, 126 made as outer

cutting members are located, and which can be made of the same material as obturator 109.

Fig. 4, 5 show shield 114 in extended protected position.

Fig. 6 shows shield 114 in retracted position.

Trocars assembly 101 operates similarly to trocar assembly 1.

- 5 Turning now to Figures 7-14, these illustrate a similar concept as applied to a penetrating end formed as a flat knife. Specifically in relation to configurations employing cutting edges provided by flat blades, it is preferred that the shield element(s) are formed as low-profile shields in a manner that they experience very low resistance to returning to their distal protective positions almost immediately that the cutting edge clears the tissue wall.
- 10 In order to better define the preferred geometrical features which ensure this rapid return of the shield to its operative position, reference will be made in the description and claims to various terminology which is defined as follows:
 - the "displacement vector" of a shield is the direction defining its retraction between its extended and retracted positions. This direction generally lies in a plane parallel to the longitudinal axis of the trocar assembly;
 - 15 - the "cutting plane" is a plane defined by a cutting edge of the flat blade and the central longitudinal axis of the device;
 - the "shield height" is the distance between the cutting plane and the outer surface of the shield as measured perpendicular to said cutting plane;
- 20 - the "shield width" is the maximal distance between the longitudinal axis of the device and the outer surface of the shield;
- the "local comparative height" of the shield is the ratio of local maximal height of the shield to the local maximal width of the shield measured in a common plane perpendicular to the device longitudinal axis;
- 25 - the "proximal protected position" of the shield is the extreme proximal position of the shield which offers complete protection of the cutting edge; and
- the "screen area" of the shield is the section of the shield which, when the shield is located in the proximal protected position, is situated between two planes perpendicular to the device longitudinal axis so that one of the planes intersects the proximal end of the cutting edge, whereas the other the plane intersects distal end of the cutting edge, and

the plane equidistant from both the perpendicular planes divides the screen area into proximal and distal screen zone.

In the case of a shield located on both sides of a flat blade such as is shown here, reference is also made to a "full local comparative height" of the shield defined as the ratio of total local maximal height of the shield and the local maximal width, wherein the total local maximal height of the shield is the distance between outer surfaces of opposite parts of the shield measured perpendicular to the cutting plane.

According to these definitions, in the case of a two-sided shield, it is particularly preferred that the full comparative height of the shield along the proximal screen area is below 1.4.

Turning now to the structural details of this embodiment, Fig. 7 shows a safety trocar assembly 201, comprising trocar unit 202 and portal unit 203.

Fig. 8 shows longitudinal section of obturator 209 distal part 227 in enlarged scale.

Obturator distal part 227 comprises penetrating apex 211 with penetrating apex cutting means looking like distal knife 228 and outer cutting member looking like proximal knife 225. Both knives - 228, 225 – are made on the plate-shaped base 229, which has two springy arms 230, 231 with ledges 232, 233 in its proximal section, said ledges ensuring engagement of plated base 229 and obturator 209. Penetrating apex shield 214 is made as two-sided low profile shield and has longitudinal slot 234 plate base 229 passes through. Bias means is made as a compression spring 216, which abuts shield 214 with its distal face 235, whereas its proximal one abuts plate-shaped base 229. In Figs. 7, 8, 12 shield 214 is in extended position so that its further distal displacement is limited by ledge 219 on plate-shaped base 229, which is abutted by shield 214 ledge 220. In Figs. 13, 14 shield 214 is in retracted position.

Device 201 operates similarly to device 1.

[Turning now to Figures 15-18, a locking mechanism according to the present invention will now be described. The lock mechanism is configured to prevent retraction of a retractable shield while the obturator is removed from the trocar, thereby protecting professional staff from accidental injury. The lock mechanism is released automatically by insertion of the obturator within the trocar, thereby allowing unimpeded retraction of the shield as required. It will be noted that this lock mechanism may be used to advantage with an otherwise conventional shield as shown here, or in combination with the preferred shield structures of the present]

[invention, as will be illustrated below.

Figs. 15, 16 show a safety trocar assembly 301 with lock means 335 for shield 336 of penetrating end 10. Device 301 comprises trocar unit 302 and portal unit 303. Portal unit 303 has tubular cannula 304 and portal housing 305. Portal housing 305 has inner seals 306 and 307 to maintain insufflation of body cavity, seal member 307 being made as O-ring, and seal member 306 as flapped valve. Trocar unit 302 has obturator 309 comprising distal part 327 and proximal part 338.

Shield 336 is made tubular and has rest ring 339. Bias spring 351 is situated between said rest ring 339 and obturator 338 proximal section.

Lock means 335 has obturator-situated controlling member 340, partially protruding laterally of obturator distal part 327 and adapted to the interaction with inner surface 341 of tubular cannula 304. Controlling member 340 is made integral with abutting member 342, having abutting surface 343. Abutting member 342 by dint of springy legs 344, 345 is spring-loaded to obturator 309.

Fig. 17 shows top view of trocar unit 302. Fig. 18 shows longitudinal section view of trocar unit 302 of Fig. 17. In Figs. 17, 18 lock means 335 is in lock position and locks shield 336 in protected position.

Shield 336 wall has elongated through slot 346 with two areas of different width – slot distal area 347 is narrower than the slot proximal area 348. Controlling member 340 has width less than that of slot distal area 347, whereas abutting member 342 is wider than slot distal area 347 but narrower than slot proximal area 348.

Therefore, when trocar unit 302 is outside portal unit 303 (Figs. 17, 18), legs 344, 345 shift abutting member 342 to lock position, in which abutting member 342 enters slot proximal area 348, and abutting surface 343 is set opposite of ledge 349 formed by the transition of slot narrow area 347 to slot wide area 348, thus precluding shield 336 proximal displacement.

Unlocking of shield 336 occurs when trocar unit 302 enters portal unit 303, but only after protected penetrating end 310 intersects distal inner seals 306, 307 so that controlling member 340 is resisted by cannula inner surface 341 and shifts abutting member 342 from the zone of its interaction with shield 336.

Device 301 operates similarly to device 1.]

Turning now to Figs. 15-25, these illustrate a particularly preferred embodiment which combines a distal-portion shield of the type illustrated in Figures 1 and 2 with a locking mechanism [of the type illustrated in Figures 15-18].

In a further preferred feature, which may be used either alone or in combination with the locking mechanism, the distal-portion shield is combined with a conventional large-diameter shield, in this case formed as concentric cylinders, to provide two-stage protection. The distal-portion shield provides immediate protection as soon as the distal portion of the penetrating end clears the tissue wall (Fig. 23), while the large-diameter shield provides additional protection once the penetrating end is fully inserted (Fig. 25). In the most preferred implementation shown here, the locking mechanism is operative to lock both shields when the obturator is removed.

More specifically, Figure 15 shows safety trocar assembly 401 with mutually independent shields 414, 436. Device 401 comprises trocar unit 402 and portal unit 403. Portal unit has tubular cannula 404 and portal housing 405.

Fig. 16 shows a left-hand view of device 401.

Fig. 17 shows a longitudinal section view of device 401.

Trocar unit 402 has obturator 409 comprising distal part 427 and proximal part 438. Penetrating end 410 comprising penetrating apex 411, sloping side wall 412 and outer cutting members 425, 426 450 with cutting edges 451 protruding above the sloping side wall 412 level. There are two tubular shields: penetrating apex shield 414 and outer shield 436. There are two independent, separate for both shields 414 and 436 bias means made as compression springs 416, 451. There is common for both shields 416, 436 lock means 435 comprising obturator-situated controlling member 440, partially protruding laterally of obturator distal part 427, and adapted to the interaction with inner surface 441 of tubular cannula 404. Controlling member is made integral with abutting member 442, having outer abutting surface 443 and inner abutting surface 452. Abutting member 442 by springy legs 444, 445 is spring-loaded to obturator 409.

Fig. 18 shows a longitudinal section of trocar unit 402 of device 401.

Fig. 19 shows top view of trocar unit 402.

In Fig. 18, 19 lock means 435 is in lock position and locks shields 414 and 436 in protected position. Shield 436 wall has through elongated slot 446 with two different-width sections - distal section 447 is narrower than proximal section 448. Controlling member 440 has width

less than that of slot 447 distal section, whereas abutting member 442 is wider than distal section 447 but narrower than slot 448 proximal section.

When trocar unit 402 is outside portal unit 403 (Figs. 18, 19), legs 444, 445 shift abutting member 442 to the lock position, when abutting member 442 partially enters slot 446 proximal

5 section 448, and outer abutting surface 443 is set opposite of ledge 449 on outer shield 436, precluding shield 436 distal displacement, and inner abutting surface 452 is set opposite of proximal face 453 of penetrating apex shield 414, also precluding shield 414 proximal

displacement. Unlocking of both shields 414, 436 occurs with trocar unit 402 entering portal unit 403, which takes place when controlling member 440 interacts with cannula 404, and thus

10 forces abutting member 442 out of interaction zone with shields 414, 436.

Figs. 20-25 show operating shields on successive stages of penetrating end 410 passing through body cavity wall 454.

Fig. 20 shows starting moment of trocar assembly 401 interaction with body cavity wall, when outer shield 436 is between its extended and retracted positions, penetrating apex shield 414 is 15 in retracted position, and penetrating apex 411 has incorporated into body cavity wall 454.

Fig. 21 shows the moment when both shields 414, 436 are forced out by body cavity wall tissue to retracted position.

Fig. 22 shows the moment when both shields 414, 436 are in retracted position, and penetrating apex 411 has penetrated into body cavity.

20 Fig. 23 shows the moment immediately after the displacement of penetrating apex shield 414 to extended protected position. In this process, outer cutting members 426, 426, 450 continue cutting tissue.

Fig. 24 shows the moment before shield 436 operation.

Fig. 25 shows both shields 414, 436 in extended position.

25 As can be seen, independent performance of shields 414 and 436 greatly ensures trocar safe operation.

Turning now to Figs. 26-31, these show a further embodiment of the present invention as applied to an obturator 509 with a distal knife 528. In this case, a one-sided low profile shield 514 is used. Since the cross-sectional area of the shield adds relatively little to the cross-

30 sectional area of the knife itself, the shield advances through the incision to its distal position to

provide protection almost immediately on penetration of the tissue wall. Preferably, according to the terminology defined above, the shield local comparative height along the proximal screen area for a one-sided shield is below 0.8.

Fig. 26 shows safety trocar assembly 501 with one-sided low profile shield 514. Device 501 has trocar unit 502 and portal unit 503. Portal unit 503 has cannula 504 and portal housing 505.

Fig. 27 shows the view of device distal part 523 from the side of penetrating apex cutting means made as distal knife 528.

Fig. 28 shows left-hand view of device 501.

Fig. 29 shows device distal part 523 from the side of shield 514..

Fig. 30 shows longitudinal section of device distal part 523 when shield 514 is in extended position.

Trocarr unit 502 has obturator 509 with penetrating end 510 with sloping side wall 512 and outer cutting members 525, 526 so that outer cutting members 525, 526 are made integral with obturator 509. Indented distal knife 528 is made on plate-shaped base 529, and has one-sided low profile shield 514 with bias means made as compression spring 516.

When penetrating end 510 passes through body cavity wall, the tissue resistance force shifts shield 514 to retracted position (Fig. 31), and stripped knife 528 makes an orifice in the tissue.

Low profile protectors, both one-sided, and two-sided – are the protectors against instantaneous operation, i.e. they operate upon knife minimal penetration to body cavity.

Turning now to Figures 36-40, these illustrate an alternative principle which may be used to avoid injury to internal organs by combining a relatively small blunt apex with one or more blade following proximally thereof. When used to penetrate the fixed wall of the abdomen, the blunt apex forces apart the tissue to initiate penetration, while the following blades enlarge the incision to the extent required. With respect to the more mobile internal organs, the blunt apex pushes aside the organs without causing damage.

Fig. 36 shows a safety trocar assembly 601 with blunt apex 655. Device 601 comprises trocar unit 602 and portal unit 603. Trocar unit 602 comprises obturator 609 with penetrating end 610. Penetrating end 610 has sloping side wall 612, cutting means made as cutting arrisis 625, 626 of penetrating end 610 material. Distally of cutting arrisis 625, 626 there is a blunt apex 655.

The blunt apex sizes are chosen so that it passes through body cavity wall tissues with slight

[resistance, and entering a body cavity, for instance, abdominal cavity, it draws movable organs – intestinal loops, big epiploon – aside, without injuring them. Therewith, blunt apex tip 656 can be rounded with rounding radius within 0.5 to 2.5 mm. However, the preferential rounding radius is within 0.75-1.5 mm.

5 The blunt apex motion effort through tissue can be diminished if blunt apex 657 is made pointed (Fig. 40), but the meeting angle for surfaces 658, 659 should be above 90 degrees, preferentially above 120 degrees. In such embodiment apex retains its function of blunt apex, i.e. it preserves all the benefits of rounded blunt apex 656 with facilitated passing through tissue.]

10 Figures³²⁻⁴¹ show a further embodiment which supplements the embodiment of Figures 36-40 with shields for the lateral blades. Advantageously, the shield may be formed in such a manner as to provide protection for the distal portion of the blade while the proximal portion is still operative, thereby providing enhanced protection.

Fig. 32 shows safety trocar assembly 701 with one-sided low profile inverted shield 736.

15 Device 701 has trocar unit 702 and portal unit 703. Portal unit 703 has cannula 704 and portal housing 705. Trocar unit has obturator 709 (Fig. 34 – top view of device 701 distal part 723) with penetrating end 710. Penetrating end 710 comprises blunt apex 755, sloping side wall 712, two knives 725, 726 and inverted shield 736.

Fig. 35 shows device distal part 723 from the side of knives 725, 726,

20 Fig. 36 shows device distal part 723 from the side of shield 736.

Fig. 37 shows longitudinal section of device 701.

Fig. 38 shows longitudinal section of device 701 trocar unit 702. Trocar assembly 701 has lock means 735 for shield 736. Lock means 735 has obturator-situated controlling member 740, partially protruding laterally of obturator 709 and adapted to the interaction with inner surface 741 of cannula 704. Controlling member 740 is made integral with abutting member 742, having abutting surface 743. Abutting member 742 is spring-loaded to obturator 709 by springy legs 744, 745. Shield 736 has abutting bar 758. When trocar unit 702 (Fig. 38) is outside the portal unit 703, legs 744, 745 shift abutting surface 743 to the level of abutting bar 758, and such mutual disposition of shield 736 and lock means 735 is the lock position which prevents shield 736 proximal displacement.

Unlocking of shield 736 takes place when trocar unit 702 is introduced to portal unit 703 but only after protected penetrated end 710 passes through distal inner seals 706, 707 so that controlling member 740, being resisted by cannula 704 inner surface 741, shifts abutting member 742 from the interaction zone with abutting bar 758.

- 5 Figs. 39, 40, 41 show longitudinal section of device 701 distal part 723 in enlarged scale at shield 736 various performance stages.

Fig. 39 shows shield 736 in extended position. Shield 736 is made plated and besides abutting bar 758 has protection edges 759, 760, guiding slots 761, 762, through which cotters 763, 764 are passing, window 765, wherein bias compression spring 716 is mounted, whose distal end 10 abuts shield 73, whereas proximal end 766 is fixed to plate-shaped base 729 of knives 725, 726. Shield 736 is an inverted shield which means that when it shifts from extended position to retracted position, the opening of knives 725, 725 starts from their proximal sections 767, 768. This operation mechanism of shield 736 is achieved owing to the fact that relative to the device longitudinal axis the incidence angle of the line connecting distal point 769 and proximal point 15 770 on protection edge 759 is more acute than the incidence angle of the line connecting distal and proximal points 771, 772 on knife 725.

Fig. 41 shows shield 736 in retracted position. Consequently, as penetrating end 710 enters body cavity, closing of knives 725, 726 starts from their distal sections which ensures low injury level.

20 The embodiment of Figures 42-49 generally parallels the embodiment of Figures 32-41, but provides independently operative shields for the lateral blades. Thus, Fig. 42 shows a safety trocar assembly 801 with two independent low profile inverted shields 836, 871. Device 801 comprises trocar unit 802 and portal unit 803. Portal unit 803 comprises cannula 804 and housing 805.

25 Fig. 43 shows left-hand view of device 801 in enlarged scale.

Fig. 44 shows device 801 distal part 823 in enlarged scale. Trocar unit 802 comprises obturator 809 with penetrating end 810 which is formed by blunt apex 855, sloping side wall 812, with protection edges 859, 860 of shields 836, 871, and knives 825, 826 protruding above it. Shields 836, 871 are made plated and equipped with independent bias compression springs 816, 851.

30 Knives 825, 826 (Fig. 47) are made on plate-shaped bases 829, 872.

Figs. 45-49 show mutual arrangement of knives 825, 826 and shields 836, 871 at various operation stages of shields 836, 871. Fig. 45 shows both shields 836, 871 in extended-protected position. Figs. 46, 47 show shields 836, 871 in intermediate position between extended and retracted position, when only proximal sections 867, 868 of knives 825, 826 are open. Figs. 48, 5 49 show shields 836, 871 in retracted position, when both knives 825, 826 are open along their entire lengths.

Figs. 45-49 show symmetrical operation of shields 836, 871, but inasmuch as shields 836, 871 are made independent and are equipped with independent bias springs 816, 851, so the 10 operation of shields 836, 871 can be independent, non-simultaneous (not shown on Figs.). The operation non-simultaneity stems from resistance non-simultaneity of tissue elements of body cavity wall. That is the concept of independent shields permits to take into account and to respond automatically to local properties of tissues.

However, for the surgeon the mode of device 801 operation does not differ from that of similar alternative devices.

15 Figures 50-63 illustrate an alternative type of shield for lateral blades, in this case combined with a distal knife and shield similar to those of Figures 26-31. The lateral shields are here implemented as resilient elements which react substantially independently to force applied near their distal and proximal ends. As a result, this configuration also provides protection for the distal portion of the blades while the proximal portion is still operative (Figures 61 and 62).

20 Fig. 50 shows perspective view of safety trocar assembly 901 comprising trocar unit 902 and portal unit 903. Portal unit 903 has cannula 904 and housing 905. Trocar unit has obturator 909 with penetrating end 910. Penetrating end is formed by sloping side wall 912, penetrating means 973 for orifice formation in body cavity wall, and protector means 913 for said 25 penetrating means 973. Penetrating means 973 comprises penetrating zones formed by knives 928, 925, 967, 926, 968 made on common plate-sided base 929 (Fig. 53) so that knives 925 and 967, as well as knives 926 and 968 have cutting edges confluent with one to another. Each penetrating zone has protector member, and each protector member has its own bias member. For penetrating zone 928 made as indented knife, protector member is made as plane-shaped shield 914, whereas bias member as compression spring 916.

30 Protector members 969 and 970 of knives 925, 967 have bias means 951, 979, respectively, so

that protector members 969, 970 are made as a common shield 936. Common shield 936 and bias means 951, 979 are made as a single resilient part, having a slat 980, which in extended position (Figs. 51, 52, 53) is situated parallel to cutting edge of knives 925, 967, and bias means 951, 979 made as resilient elements, each of them being connected to slat 980 by one its end 981, 982, whereas the other one 983, 984 is connected to the plate-shaped base 929. Protector members 985 and 986 of knives 926 and 968 have bias means 987, 988, respectively, so that protector members 985, 986 are made as a single resilient part, having a slat 990 which in extended position is situated parallel to cutting edges of knives 926, 968, and bias means 987, 988 are made as resilient elements, each of them being connected to slat 980 by one its end 991, 992, whereas the other ones 993, 994 are connected to the plate-shaped base 929.

Figs. 55-63 show mutual arrangement of protector members at various stages of penetrating end 910 passing through body cavity wall 954.

Fig. 55 shows shields 914, 936, 989 in extended position.

Fig. 56 shows shield 914 in retracted position, and open knife 928 creates an orifice in body tissue.

Fig. 57 shows protector members 969, 985 displaced to retracted position, and knives 925, 926 create orifice in body tissue.

Fig. 58 shows all shields 914, 936, 989 in retracted positions.

Fig. 59 shows knife 928 entry to body cavity.

Fig. 60 shows the point immediately after shield 914 displacement to extended protected position.

Fig. 61 shows knives 925 and 926 entry to body cavity, one of them 925 being shown protected by protector member 969, which displays independent operation of symmetrical protector members 969 and 985, thus ensuring maximal fast operation of protector members, and, consequently, minimal injury of internal organs.

Fig. 62 shows protector members 914, 969, 985 in extended-protected position.

Fig. 63 shows penetrating end 910 as totally entering the body cavity, with totally protected penetrating means.

Figures 73-76 illustrate a configuration generally similar to that of Figures 36-39 but wherein]

[the lateral blades are formed with graduated sharpness decreasing from distal to proximal. This helps to prevent over-broadening of an incision during insertion. Thus, Fig. 73 shows a safety trocar assembly 1001 comprising trocar unit 1002 and portal unit 1003. Portal unit 1003 has cannula 1004 and housing 1005. Trocar unit 1002 has obturator 1009 with penetrating apex 1010. Penetrating apex 1010 is formed by blunt apex 1055, sloping side wall 1012, and cutting means. Cutting means is made as two sharpened protrusions 1025, 1026 on sloping side wall 1012 so that protrusions 1025, 1026 are made with decreasing proximal sharpness, which ensures tissue cutting at the proximal level of protrusions 1025, 1026 at higher tissue tension than by tissue cutting at the distal level of protrusions 1025, 1026. Such mechanism of tissue cutting precludes generation of excessive diameter orifice in body cavity wall.]

Figures^{64–68} show an embodiment generally similar to that of Figures 50–53, but wherein the resilient elements are formed with greater spring resistance at their rear proximal end than at their distal end, thereby also tending to preclude over-widening of the incision.

Fig. 64 shows a safety trocar assembly 2001 comprising trocar unit 2002 and portal unit 2003. Portal unit 2003 has cannula 2004 and housing 2005. Trocar unit has obturator 2009 with penetrating end 2010. Penetrating end is formed by sloping side wall 2012, penetrating means 2073 for orifice formation in body cavity wall, and protector means 2013 for said penetrating means 2073. Penetrating means 2073 comprises penetrating zones formed by knives 2028, 2025, 2067, 2026, 2068 made on common plate-sided base 2029 (Fig. 65^{66,67}), so that knives 2025 and 2067, as well as knives 2026 and 2068 have cutting edges confluent into each other. Each penetrating zone has protector member, and each protector member has its own bias member. For penetrating zone 2028 made as indented knife, protector member is made as plate-shaped shield 2014, and bias member is made as compression spring 2016.

Protector members 2069 and 2070 of knives 2025, 2067 have bias means 2056, 2079, respectively, so that protector members 2069, 2070 are made as a common shield 2036. Common shield 2036 and bias means 2051, 2079 are made as a single resilient part, having a slat 2080, which in extended position (Figs. 64, 65) is situated parallel to cutting edges of knives 2025, 2067, and bias means 2051, 2079 are made as resilient elements, each of them being connected to slat 2080 by one its end 2081, 2082, whereas the other one 2083, 2084 is

connected to the plate-shaped base 2029. Protector members 2085 and 2086 of knives 2026 and 2068 have bias means 2087, 2088, respectively, so that protector members 2085, 2086 are made as a common shield 2089. Common shield 2089 and bias means 2087, 2088 are made as a single resilient part, having a slat 2090, which in extended position is situated parallel to cutting edges of knives 2026, 2068, and bias means 2087, 2088 are made as resilient elements, each of them being connected to slat 2090 by one its end 2091, 2092, whereas the other ones 2093, 2094 are connected to the plate-shaped base 2029. In this, proximal bias means 2079 is made more rigid than distal bias means 2051, consequently, the displacement of proximal protector member 2070 and knife 2067 opening, and further on, tissue cutting at this level of 10 penetrating means occurs at higher tissue tension than by tissue cutting at the level of knife 2025.

Shield 2089 operates in similar manner.

Such tissue cutting mechanism precludes generation of excessive diameter orifice in body cavity wall.

15 Figures 69-72 show an embodiment generally similar to that of Figures 32-41, in which the shield is formed with a stepped edge. The inclination of the steps to the longitudinal axis of the assembly varies from greatest at the distal part of the shield to least at the proximal part of the shield. This tends to ensure that less force is required to cause retraction of the shield at smaller diameters of hole than at large diameters, thereby limiting over-widening of the incision. Thus,

20 Fig. 82 shows safety trocar assembly 3001 with low profile inverted shield 3036. Device 3001 has trocar assembly 3002 and portal assembly 3003. Portal assembly 3003 has cannula 3004, and housing 3005. Trocar assembly has obturator 3009 with penetrating end 3010 formed by blunt apex 3055, and sloping side wall 3012, with protector edges 3059, 3060 of shield 3036 and knives 3025, 3026 protruding over it.

25 Trocar assembly 3001 has lock means 3035 for shield 3036. Lock means 3035 has obturator-situated controlling member 3040, partially protruding laterally of obturator 3009, and adapted to the interaction with inner surface 3041 of cannula 3004. Controlling member 3040 is made integral with cutting member 3042, having abutting surface 3043. Abutting member 3042 by springy legs 3044, 3045 is spring-loaded to obturator 3009. Shield 3036 has abutting bar 3058.

30 When trocar unit 3002 is outside portal unit 3003, legs 3044, 3045 shift abutting surface 3043

to the level of abutting bar 3058, and such mutual arrangement of shield 3036 and lock means 3035 is the lock position (not shown in the Fig.), wherfrom shield 3036 proximal displacement is impossible.

5 Figs. 70, 71, 72 show longitudinal section of device 3001 distal part 3023 in enlarged scale at various stages of shield 3036 operation.

Fig. 70 shows shield 3036 in extended position. Shield 3036 is made plated and has, in addition to abutting bar 3058 and protection edges 3059, 3060, guiding slots 3061, 3062, through which cutters 3063, 3064 are passing, window 3065, wherein bias compression spring 3016 is mounted, abutting shield 3036 by its distal end, and fixed to plate-shaped base 3029 by its 10 proximal end.

Fig. 70 shows shield 3036 in the position intermediate between extended and retracted ones.

Fig. 71 shows shield in retracted position.

Protector edges 3059, 3060 are made stepwise with varying slope of steps 3095 so that in distal-proximal direction the slope of steps 3095 relative to device 3001 longitudinal axis decreases, and, consequently, in the same direction decreases the force of steps 3095 engagement with the tissue, hence, larger tension is required for shield 3036 proximal displacement upon tissue interaction with proximal steps than it is for tissue interaction with distal steps, and hence, cutting of tissue at the level of distal sections 3025, 3026 occurs with smaller tissue tension than at the level of proximal sections of knives 3025, 3026. Such tissue 15 cutting mechanism precludes generation of excessive diameter orifice in body cavity wall. 20

Figures 86-89 illustrate a further principle of the present invention, useful either alone or in combination with other features described above. According to this feature, the cannula is configured to provide a distally projecting portion which is co-extensive in the axial direction with at least one cutting edge of the obturator. As a result of this structure, the projecting 25 portion of the cannula is already located within the incision while the cutting process is still progressing, thus ensuring that the size of the incision accommodates the lateral dimensions of the cannula without causing further damage to the tissue by forced insertion through an undersized incision.

Fig. 86 shows a perspective view of trocar assembly 4001. Device 4001 has trocar unit 4002 and portal unit 4003. Portal unit 4003 has housing 4005 and tubular cannula 4004. Cannula has]

open distal end 4008, having sloping edge 4036. Trocar unit 4002 has obturator 4009 with penetrating end 4010, whereon knife 4025 is situated so that knife 4025 proximal end 4067 is located proximally of distal point 4097 of sloping edge 4096. With such mutual arrangement of sloping edge 4096 and knife 4025 maximally non-injurious advance of penetrating end through body tissues takes place, as knife 4025 cuts tissues stretched by sloping edge 4096, thus precluding their rupture.

Fig. 90 shows trocar assembly 5001 with mounting means 5098. Device 5001 has trocar assembly 5002 and portal unit 5003. Trocar assembly 5002 has obturator 5009 with penetrating end 5010. Portal unit 5003 has tubular cannula 5004, housing 5005, inner seals 5006, 5007, and mounting means 5098. Mounting means 5098 comprise inflated cuff 5099 mounted on cannula 5004, connector 5100 with rebound valve 5101, passage 5102 made in cannula 5004 wall and connecting connector 5100 with cuff 5099. Mounting means 5098 also has outer mounting means comprising restraining member 5103 movable along cannula 5004, and resistance means precluding spontaneous proximal displacement of restraining member 5103. Restraining member 5103 has a flange 5108 and an orifice 5104 the cannula 5004 passes through. Resistance means is made as an engagement protrusion: cannula engagement protrusion 5105 and restraining member engagement protrusion 5106. In this embodiment, engagement protrusion 5105 and 5106 are situated spirally, permitting to shift restraining member 5103 along cannula 5004 by its rotation. Device 5001 also has means for gas feeding into body cavity, comprising connector 5107 and passes 5108.

Device 5001 operates as follows.

Fig. 90 shows the device in ready-to-work view, when cuff 5099 is deflated, and restraining member 5103 is in proximal position. Body cavity wall is pierced in usual manner. After cuff 5099 introduction into body cavity, trocar unit 5002 is removed. Cuff 5099 is inflated via connector 5100, and then by drawing housing 5005 inflated cuff 5099 is pressed against body cavity wall 5054, whereas restraining member 5103 is pushed toward cuff 5099 until the restraining member 5103 is pressed against body cavity wall 5054 (Fig. 94). Portal unit 5003 set in this way is well fixed at the body cavity wall 5054, which precludes its accidental displacement during introduction and removal of surgical instruments through portal unit 5003.

Compression of body cavity wall tissues between cuff 5099 and restraining member 5103.]

[generates additional hemostasis in cut tissues and serves as a sealing factor, precluding gas leakage out of body cavity through the clearance between cannula 5004 and orifice walls. To remove portal unit 5003 from body cavity wall, cuff 5099 is deflated.]

5 Although the present invention has been shown and described in terms of preferred embodiments, it will be appreciated that various changes and other modifications are contemplated within the spirit and scope of the present invention as defined by the following claims.